DESIGN TECHNIQUES TO STRENGTHEN 'SOFT BUILDINGS' AGAINST ACTS OF TERROR AND CAR BOMBS

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ABSTRACT

Since 1994, MYY Ltd. (Israel) has been in the process of developing and testing new methods and products for hardening of "soft buildings" against acts of terror and Car Bomb attacks. The design methodologies that will be presented are based on practical experience in detailed design of retrofit projects, testing of retrofit systems and the numerous investigations of actual bombings around the world. MYY Ltd. has collaborated with U.S. Agencies and will present the development and testing of the following systems:

SHIELDING THE BLAST WITH EXTERNAL LIGHT WALLS: Shielding of the initial reflected pressure can be achieved with relatively light or even movable walls. Shielding walls have proven to be efficient, at relatively close standoff distances and at reducing the reflected peak pressure in one order or more.

"WET" AND "DRY" RETROFIT OF MASONRY WALLS: Concrete skins are efficient and cost effective for hardening of external walls. Durisol bricks, filled with concrete, provide an ideal system for close setbacks. Design properties include architectural and structural advantages, simple logistics and ease of construction. These systems have been tested for equivalent levels of protection with "built in" windows and doors.

CABLING SYSTEMS COMBINED WITH WINDOWS AND GLASS CURTAIN WALLS: The goal of this technique is to protect people from flying glass. Cabling systems provide a solution to the problem. Windows and curtain walls, combined with the cabling system, have been tested to meet loads of about 60 psi.

- *LIGHT STEEL DOORS FOR NEW CONSTRUCTION AND RETROFIT: Retrofit doors have been designed to be installed on standard wooden frames of existing construction. The design is light, architecturally pleasing and looks like standard office doors. The design door withstands blast leakage levels of about 100 psi/msec. The design has also been tested to meet ballistic threat level criteria.*

INTRODUCTION

During the 1991 Gulf War, missiles with conventional warheads using High Explosives attacked the civilian population of Israel. Most of the missiles exploded near residential apartment buildings typically made of reinforced concrete, beams and columns; and standard masonry construction. A large number of apartments were heavily damaged, but the buildings did not collapse even when missile impact was very close. About 500 persons were injured, mainly from secondary glass fragments and flying building materials.

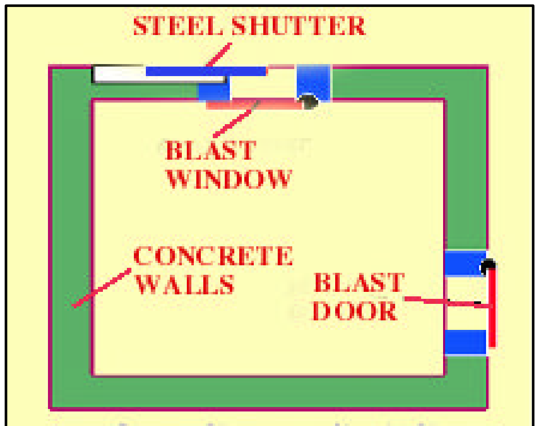

Figure 1: Protected Space

After the Gulf War, a new construction concept was developed. The design of residential dwellings would incorporate a solid tower of "protective spaces." In each new apartment building, one bedroom is made of reinforced concrete, with a light blast-resistant door and window. In an emergency, an external steel shutter would cover the blast window. The protective spaces are also airtight, which provides protection against nuclear, biological and chemical (NBC) warheads.

Since 1994, we have been developing and testing new methods and products to harden "soft buildings" against acts of terror, and car bomb attacks in particular. Between 1991 and 1998, we subjected protected spaces and structural members to a series of seven different tests to study blast effects. Based on these tests and careful studies of actual events, including missile and car bomb attacks, we conclude that a typical building of "beams and columns" construction, will not "easily collapse" from the blast effects. However, in the cases studied, damage and casualties will be caused due to blast leakage into the building and to impacts of secondary fragments of glass and building materials.

This paper deals with Strengthening methods, which were developed, for hardening of "soft buildings" to withstand the effect of car bombs or missile attacks.

SHIELDING THE BLAST WITH EXTERNAL LIGHT WALLS

Shielding of buildings from initial or reflected blast pressures can be achieved with relatively light or even movable walls. Shield walls have been proven to be effective in reducing the reflected peak pressure by an order of magnitude, or more, at relatively close standoff distances. Shield walls can be designed to look aesthetically pleasing, while maintaining its effective shielding function.

The shielding effects of a relatively light movable protective wall were evaluated in several tests and found to be equivalent to the shielding effects of the “standard” heavy shield wall. For example, the blast performance of a standard shield wall was compared to the blast performance of a light wall using identical charges.

Figure 3 shows the behavior of peak reflected impulse pressure as compared to tested and calculated impulse. These results have been confirmed by recent tests. The pressure behind the shield wall, at the first floor level, was similar for heavy and medium charges. It appears that the shielding effect was significantly higher in the case of the large charges. Similar results were noticed in other tests. The shielding effect on impulse was measured in full-scale tests using a range of charge weights (equivalent T.N.T) from 500 lbs. to 2000 lbs.

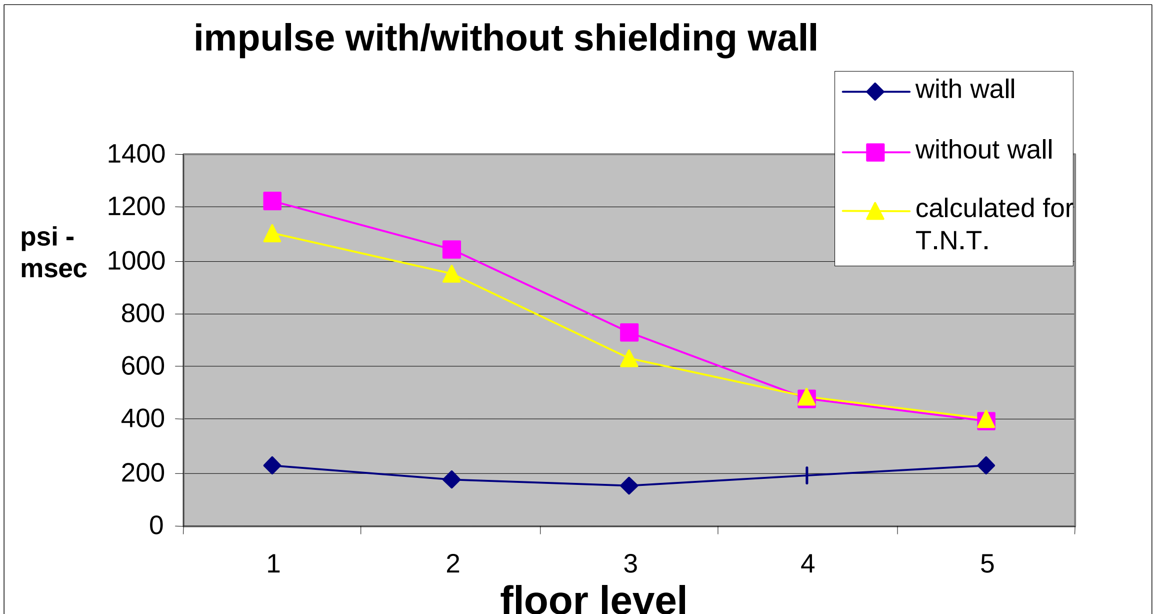

Figure 3: Behavior of Peak Reflected Impulse and Pressure in Test

“WET” AND “DRY” RETROFIT OF MASONRY WALLS

Concrete skins are efficient and cost effective for hardening external walls.

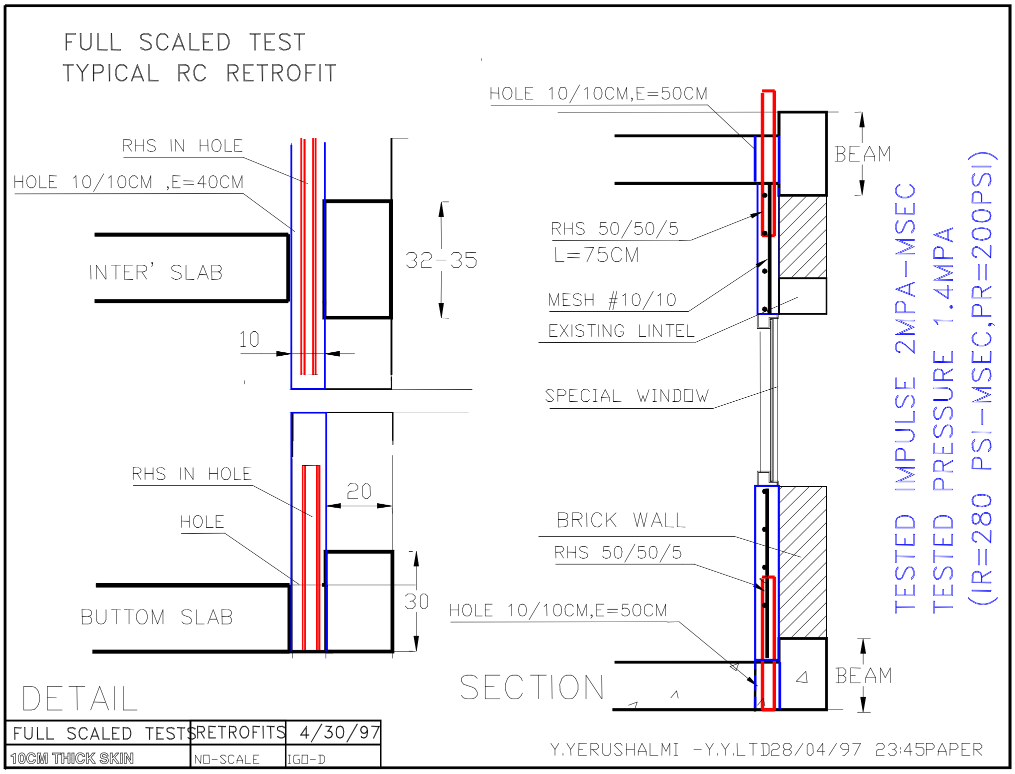

Figure 4: Section detail of retrofit with concrete skin

Wet Retrofit Systems: The concrete skin, which is applied on the surface of a masonry wall, is a single layer of reinforced concrete with central mesh. The concrete is poured into place through holes in the slabs. Good adaptations to openings (new steel frame and special window will be applied). Concrete skins can provide additional blast resistance to the building if the concrete skins are continuous. A system consisting of Durisol blocks filled with concrete provides an ideal solution for close setbacks. Durisol blocks possess architectural and structural advantages, i.e., simple logistics and transportation, and ease of construction with unskilled labor. Both the concrete skins and the Durisol system can withstand impulse loads of about 300 psi-msec.

Dry retrofit systems: Internal steel liners or Achidetex curtains can be used depending on the threat level and the degree of protection desired. Steel liners that are connected to the roof and floor slabs and covered with gypsum board can withstand impulse loads of about 220 psi-msec. The Achidetex curtain is connected to the slabs and glued to the internal face of the walls, similar to wallpaper. Such curtains can withstand impulse loads of about 150 psi-msec. Both systems can be combined with “built in” windows and doors, for the same level of protection (See picture of Achidetex curtain and special cable window).

The following is a summary of the resistance of retrofit systems, in units of reflected impulse.

Building new external walls.

Reinforced concrete section (25-30cm)	700 psi-msec
Maya-Durisol blocks (30cm)	700 psi-msec

"Wet" retrofit systems.

Reinforced concrete skin (10cm) behind blocks/bricks	300psi-msec
Maya-Durisol block (15cm) behind blocks/bricks	300psi-msec

"Dry" retrofit systems.

Steel liners behind blocks/bricks	220psi-msec
Achidetex curtain glued to the internal face	150psi-msec

WINDOWS AND CURTAIN WALLS

The primary purpose of windows and curtain walls is to protect people from flying glass. The cabling system, recently developed by MYY together with Arpal Aluminum LTD, fulfills this purpose. It "catches" the glass and debris in the window itself. Windows and curtain walls, combined with the cabling system, can meet high loads, i.e., up to about 60psi. They are extremely light (almost the same weight as commercial windows and curtains) and can be used with tilt-and-turnlocking mechanisms. The cabling system was tested recently in a series of 10 different tests. The purpose of the test series was to determine the efficiency of the cabling system combined with windows and curtain walls. The first test of curtain walls was conducted in June 1998.

Figure 7: Before Test of Glass Curtain Wall

Figure 8: After Test of Glass Curtain Wall

A heavy charge was detonated at a close distance on the exterior of the light shielding wall. The cable system had been installed in the curtain wall (left). After the test, the cable system remained in place, and stopped the glass panels and large debris from the shielding wall.

- The cable system has proven itself to be very efficient in stopping debris from laminated glass windows, curtain walls, and heavy concrete elements.
- The system was tested up to blast levels of about 10 bars and impulse of about 14 bar-msec (140 psi and impulse of about 200psi-msec).

Similar systems utilizing cables, catch bars made of steel, “steel curtain” made of steel strips serving as a shutter (operational at closed and open positions) were successfully tested and implemented in recent projects.

Standard casement cable-protected windows were developed having a tilt-and-turning locking mechanism. They appear and function like standard, normal looking windows. The window is capable of sustaining Blast Class of 50 psi pressure at 150 psi-msec impulse. The window may be installed both in retrofit and new building applications. They can be installed relatively quickly, i.e., between 10 minutes to 1 hour.

For high-risk areas, we have developed a blast and fragment resistant window. It can serve also as a ballistic and forced entry resistant window. Such windows ware tested in full-scale building tests. The blast level was about 200 psi and impulse loads of 280 psi-msec.

LIGHT STEEL DOORS FOR NEW CONSTRUCTION AND RETROFIT

The MUL-T-LOCK “Super Light” Blast Resistant Door is constructed utilizing two metal skins connected with vertical ribs, weighing 150 pounds including the metal frame. These doors can be used either for “retrofit” (with cover frame) or “new construction” (with construction frame).

The “Super Light” Door utilizes a minimum of an eight (8) point locking system to protect or mitigate the effects of blast and/or forced entry. Up to 18 locking pins can be applied. These doors can be upgraded to provide protection for desired/needed ballistics criteria. These doors will sustain a blast class (nominal) of 50 psi pressure at 100-milliseconds. The door is also fire retardant. The door can be upgraded to provide protection for desired/required ballistics criteria and significantly higher blast resistance.

The MUL-T-LOCK Ballistic Door is constructed utilizing two metal skins and armored steel plate (designed for the desired ballistic protection) connected with vertical ribs, weighing 320 pounds including the metal frame. These doors can be used either for “retrofit” and/or “new construction.” The frame would be embedded in reinforced concrete or welded to steel. The “Ballistic” Doors utilize an eighteen (18) point locking system and four (4) hinges to protect or mitigate against forced entry and increased blast levels. All the locking pins and bolts can be opened simultaneously in case of emergency. These doors will sustain a blast class (nominal) of 110 psi, and impulse of 150 psi-sec.

CONCLUSION

Methods are available for all types of walls, doors and windows to reduce the hazard of blast and fragmentation for new construction and mainly retrofit purposes.

Our job is to provide solutions for the required level of protection at minimal costs and with changes. The retrofit systems that are described in this paper were utilized in projects designed by MYY. The design of the shielding walls, retrofit of windows, and external walls must match the special conditions at each site. Sometimes retrofit design is an “art.”

We are involved in the development of various products in Israel and abroad. During 1998 alone we conducted about 40 tests of which 12 were full-scale tests.

We are studying (and visiting, if possible) the effects of actual terrorist attacks around the world. Gathering as much data as possible assists us in preparing vulnerability studies and site survey assessments.